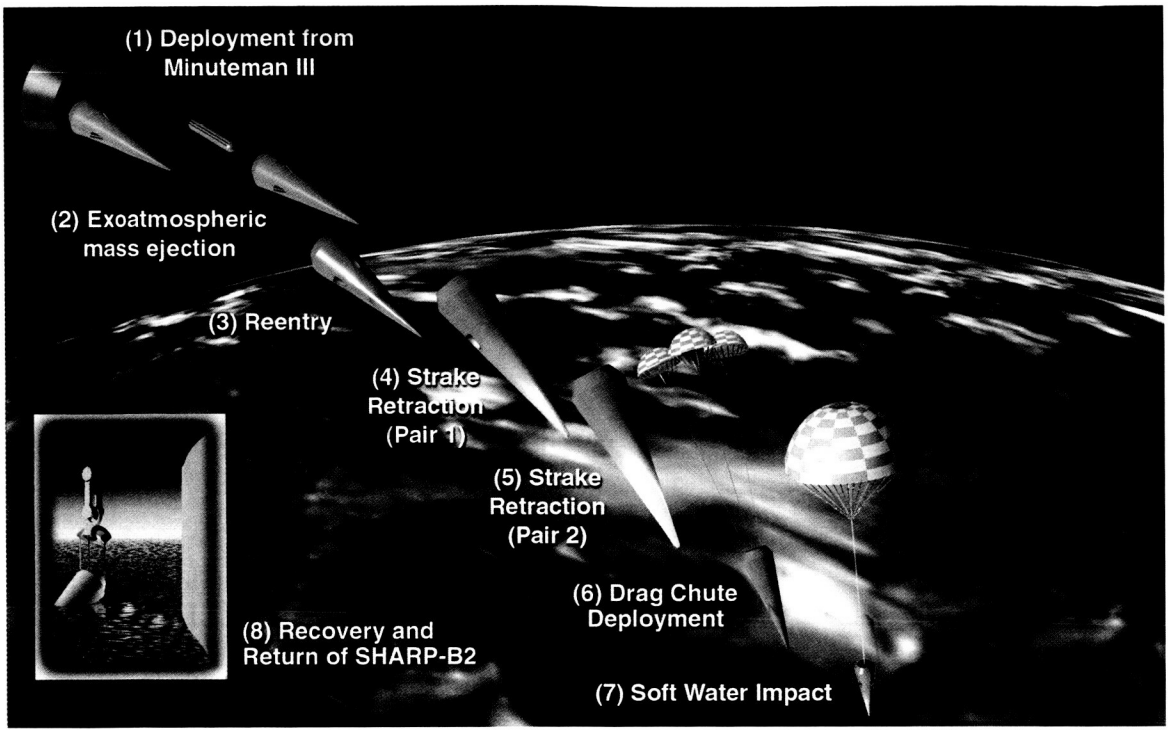


*Fig. 2. SHARP-B2 flight experiment mission scenario (28 Sept. 2000).*

## Shuttle Materials Resistant to Micrometeorite Orbital Debris

Daniel B. Leiser, David A. Stewart

This research and development program was initiated to improve the micrometeorite orbital debris (MMOD) resistance of the belly tiles on the shuttle orbiter. More specifically, it was started to establish a means for substantially improving the damage resistance and MMOD characteristics of the RCG/LI-900 shuttle baseline tile. This improvement would result in a substantially reduced amount of damage and therefore less repair between flights as observed in the toughened unipiece fibrous insulator (TUFI)/AETB tiles (fig. 1) flown in the base heat shield. The goal was to obtain a more MMOD-resistant low-density insulation with thermal conductivity equivalent to that of LI-900 so that the "new" tile could replace the baseline tile on a one-for-one basis.


*Fig. 1. Shuttle Flight Testing of L1-900/RCG vs AETB-8/TUFI in base heat shield.*

For a short-term solution, this was accomplished by developing a new surface treatment for the LI-900 that takes advantage of the Ames technology developed previously and designated as TUFI, which has the desired improved damage resistance. The program used components that minimally changed significant properties of the surface-treatment composite developed (that is, thermal expansion coefficient, thermochemical stability, and processing temperature) while at the same time developing a new functionally gradient tough tile. A prototype of this material has been produced successfully, its damage resistance has been determined, and its microstructural stability has been demonstrated. Although it has the desired thermal conductivity, since it uses LI-900, the substrate is still mechanically weak.

A longer-term solution also in the initial phases of development uses AETB-8 as the insulation substrate. This substrate is significantly stronger than the LI-900 substrate and is more compatible with the TUFI surface treatment. The solution involves developing a technique to reduce the "effective" thermal conductivity of TUFI/AETB-8 to a point where it is no longer an issue relative to using it as a substitute for an LI-900 tile on the orbiter. The modified TUFI/AETB-8 developed with a lower thermal conductivity and the improved damage resistance and MMOD characteristics of TUFI would therefore be applicable to the orbiter as a direct substitute. The first modified AETB-8 substrates have been produced. One of the authors' (Stewart) engineering model for the thermal conductivity of the composite material, has successfully predicted the thermal response of both the LI-900 and low-conductivity AETB tiles with RCG- or TUFI-treated surfaces during exposure to radiant and convectively heated environments. In the radiant heating facility, data were obtained over a pressure range from 0.001 to 1.0 atmospheres. Comparison of the predicted and measured values obtained from arc-jet data showed similar results. The resultant predicted thermal conductivity is significantly lower than that of AETB-8 alone and at temperatures above 1,500°R is below that of LI-900.

Assuming equivalent density tiles for both LI-900 and the modified AETB-8, the back-face temperature history of a tile located just forward of the nose wheel door during a typical Earth entry by the shuttle was predicted (fig. 2). The temperature profiles for an LI-900 tile at this location are very similar to the ones predicted for a low-thermal-conductivity k AETB tile. As a result, the performance of a 5.08-cm (2.0-in) -thick low k AETB tile near the front landing gear door of the vehicle would be equivalent to that of an LI-900. The research program therefore has been very successful. Prototypes of both an LI-900/TUFI tile system have been produced that have substantially improved impact resistance, and a modified AETB/TUFI has been developed with thermal conductivity equivalent to that of an LI-900.

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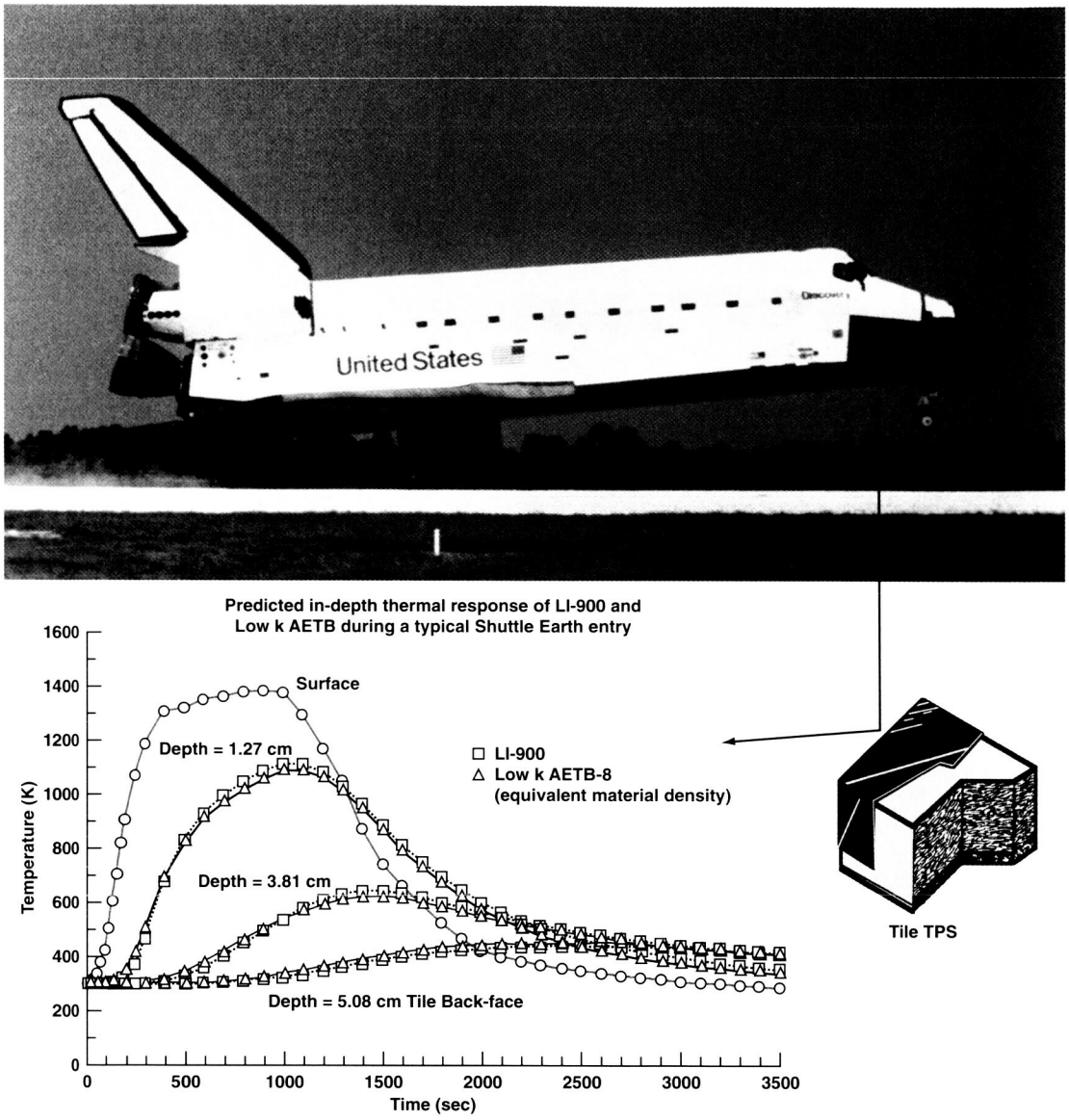


*Fig. 2. Proposed high-strength/low conductivity AETB Tile System for shuttle upgrade.*